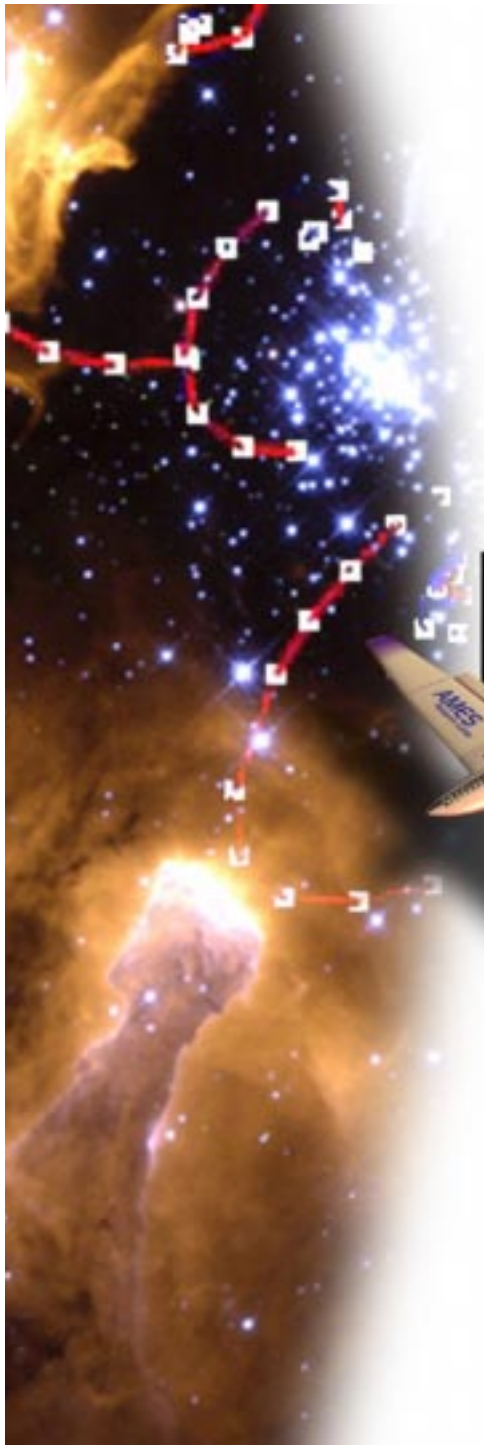
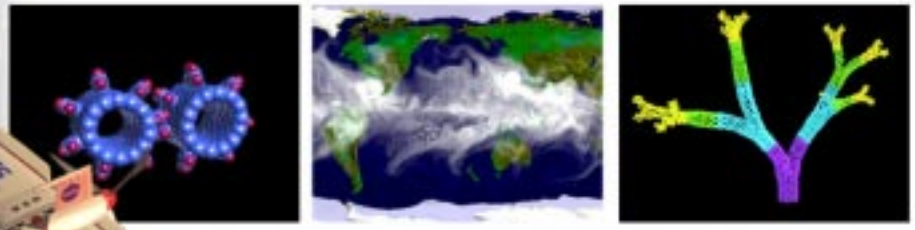


Information Technology Strategic Research Overview



David Alfano, Manager, IT Strategic Research
NASA Ames Research Center

NRC Review of PRT
June 10-14, 2002

Presentation Overview

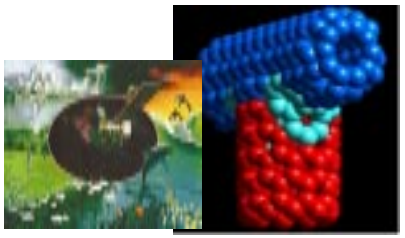
IT Strategic Research Overview - David Alfano	**20min**
High Confidence Software - Mike Lowry	**20min**
Intelligent Controls & Diagnostics - Joe Totah	**20min**
Bio/Nanotechnology - Harry Partridge	**30min**
Revolutionary Computing Algorithms - Benny Toomarian	**10min**
Evolvable Systems - Jason Lohn	**10min**

NASA Mission Requirements for CICT Technology

NASA Mid- and Long-Term Mission Plans are reliant on the availability of advanced information technologies:

- **Smarter more intelligent, collaborative systems including:**
  - ***Autonomous spacecraft control and scientific discovery***
  - ***Intelligent sensor webs and cooperating constellations***
  - ***Integrated human/robotic explorers***

- **Advanced computing and communication systems including:**
  - ***Breakthrough science and engineering simulation capabilities***
  - ***Mobile, distributed analysis, data mining, and collaboration capabilities***
  - ***Pervasive Earth-to-deep space NASA web technologies to support robotic and human exploration***



- **Information Technology Strategic Research, including:**
  - ***Intelligent controls and diagnostics***
  - ***Evolvable systems***
  - ***High confidence software***
  - ***Biotechnology and nanotechnology***
  - ***Revolutionary computing concepts***

QuickTime™ and a Photo - JPEG decompressor are needed to see this picture.

IT Strategic Research

Goal:

IT Strategic Research is the area of the CICT Program where the very new and unfolding technologies are explored and evaluated for benefit to the Agency, Enterprises, and their Programs. ITSR provides the "seed corn" in technologies from which the revolutionary technologies elsewhere in the Program and Enterprises will spring.

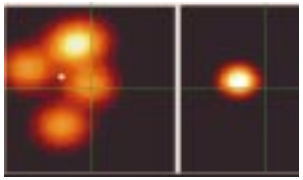
Objectives:

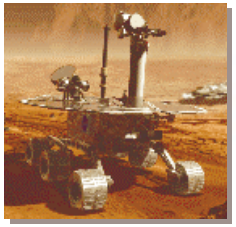
- **Explore and evaluate a broad collection of technologies for their suitability to enable revolutions in the way NASA's missions are accomplished.**

- **Research, develop, and evaluate a broad portfolio of fundamental information and bio/nano technologies for infusion into NASA missions.**

IT Strategic Research Roadmap

Mission Impact




Enterprise Benefit (notional)

Capabilities

2001-2005	2005-2010	2010-2015	
• Scalable aerospace software verification technology	• Auto-synthesis of certified software systems	•Widespread robotic construction of software	R, S, M, Y
• Next-generation evolutionary algorithms	• Self-reconfiguring hardware systems	•Defect-tolerant, self-improving micro spacecraft	S, R, M, Y
• Third-generation neural flight control algorithms	• Biomimetic control architectures	•Intelligent Maneuvering	R, S, M
• Evolutionary algorithms for on-board space computation	• Quantum algorithms for computationally hard problems	•Revolutionary computing platforms	Y, S
• Nanoscale assembly techniques	• Biomolecular systems	•Self-repairing nanosystems	R, S, M, Y, U

Alignment with Enterprise Goals

ITSR is exploring revolutionary and breakthrough research in alignment with Enterprise goals:

Aerospace Technology (Code R):

"Develop new technologies to enable innovative and less expensive research and flight missions."

Human Exploration and the Development of Space (Code M):

"Invest in the development of high-leverage technologies to enable safe, effective and affordable human/robotic exploration."

"Enable human exploration through collaborative robotic missions."

Space Science (Code S):

"Develop new technologies to enable innovative and less expensive research and flight missions."

"Use robotic science missions as forerunners to human exploration beyond low-Earth orbit."

Earth Science (Code Y):

"Develop advanced technologies to enable mission success and serve national priorities."

Biological and Physical Research (Code U):

"Develop strategies to maximize scientific research output on the ISS and other space research platforms."

"Identify mechanisms of health risk and potential physiological and psychological problems to humans living and working in space, and begin developing countermeasures."

Alignment with Enterprise Needs

NASA Challenges

Goal-Directed, Reliable, Adaptable and Self-Healing Systems for Aerospace, Planetary Exploration and Space Missions

Science community desires more science data

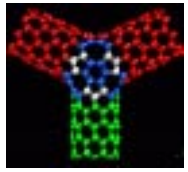
Agency need to keep up with newer technologies to meet mission requirements

Need to balance need for breakthrough technologies with investment limits

Transition of new technologies to missions

Technology Solutions

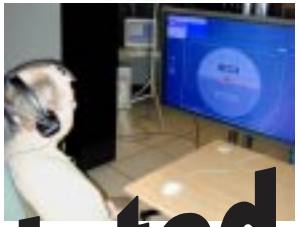
- **High-confidence software verification and synthesis**



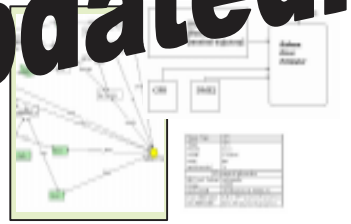
- **Evolvable systems for survivability/function**

- **Neural-based control of vehicles and systems**

- **New human/machine interface modalities**



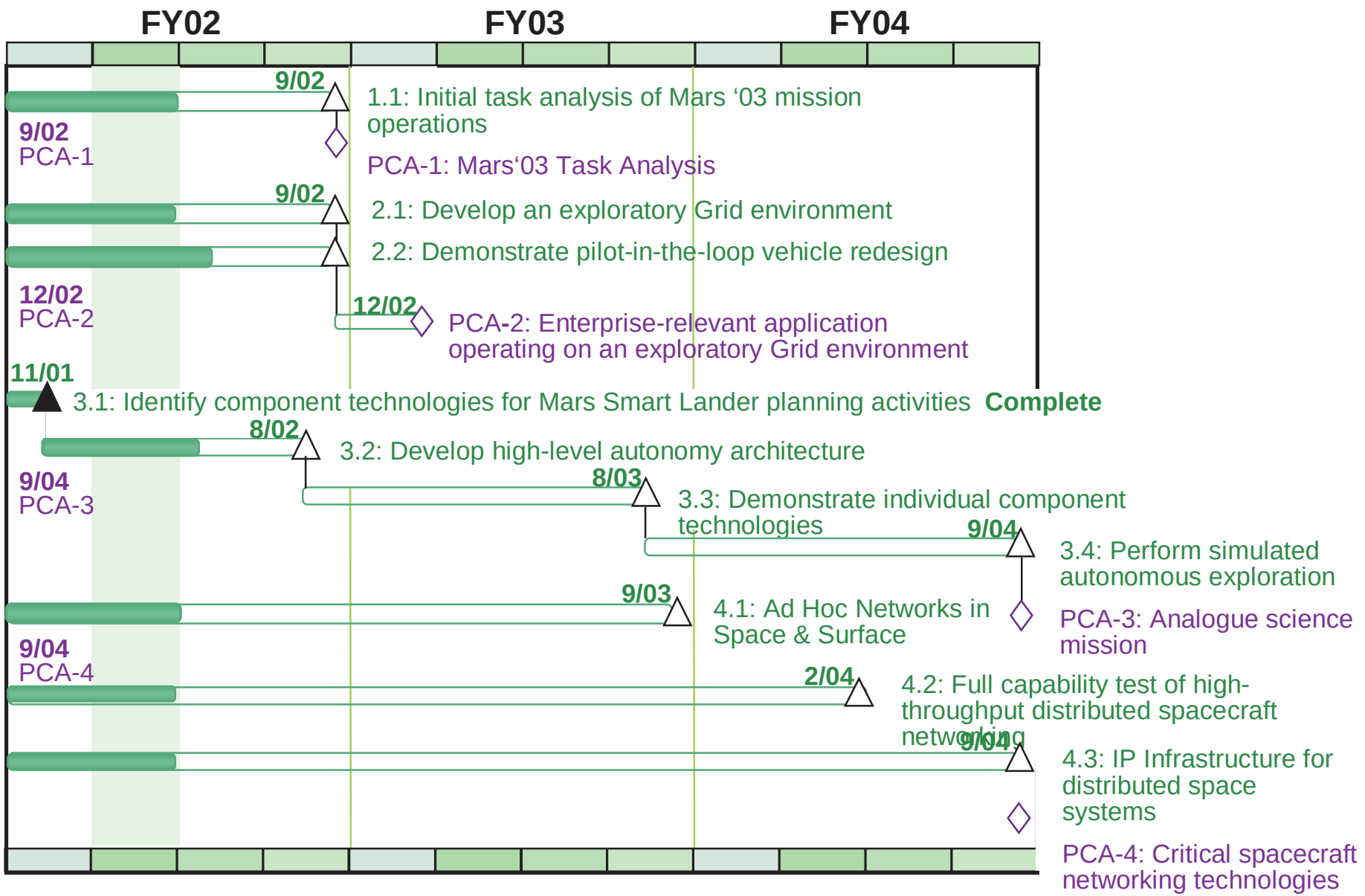
- **Bio-inspired and nanoscale computing and electronics**



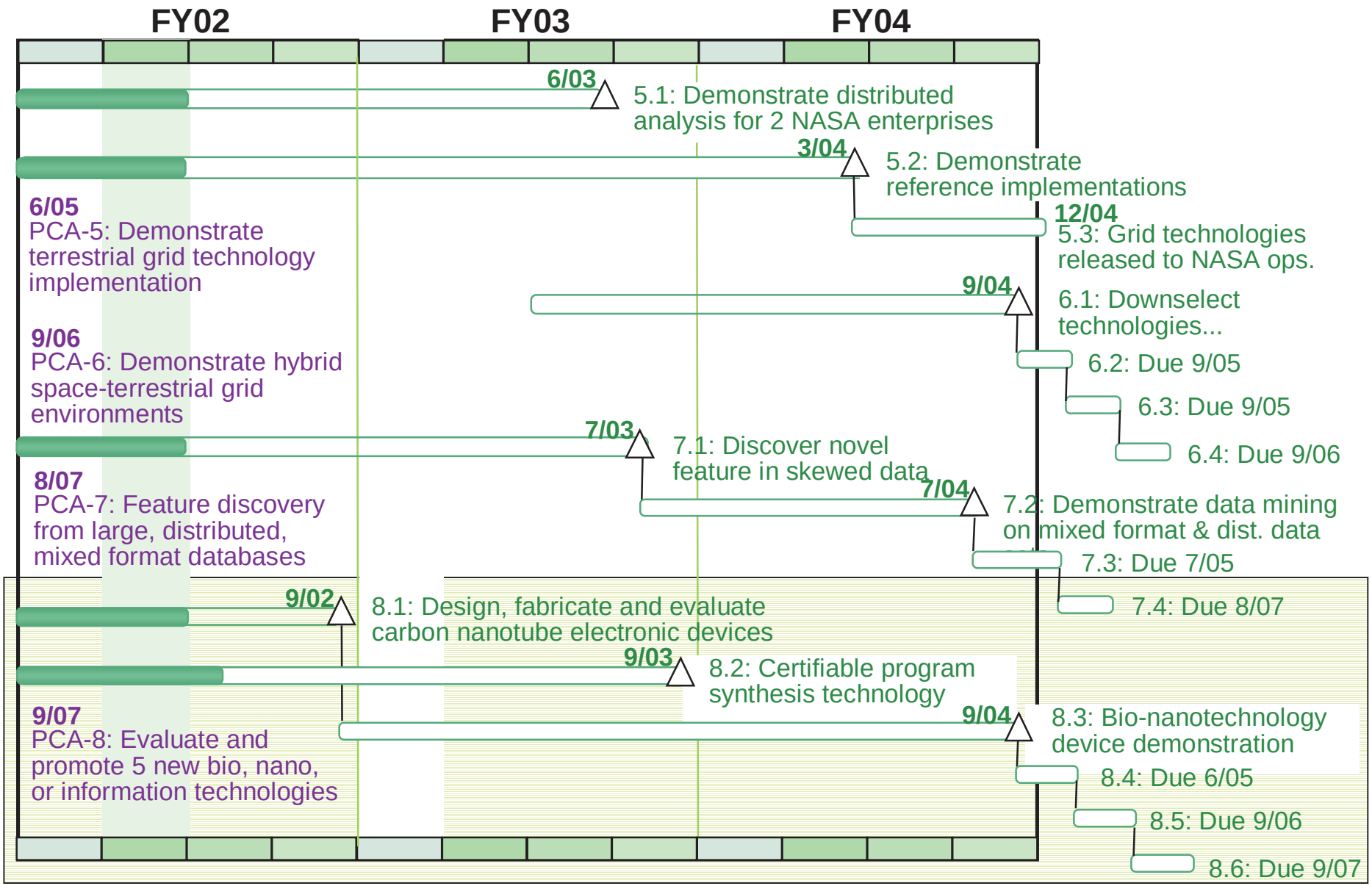
- **Algorithms for quantum computing**

to be updated...

CICT PCA/Program FY02-04 Milestones



CICT PCA/Program FY02-04 Milestones

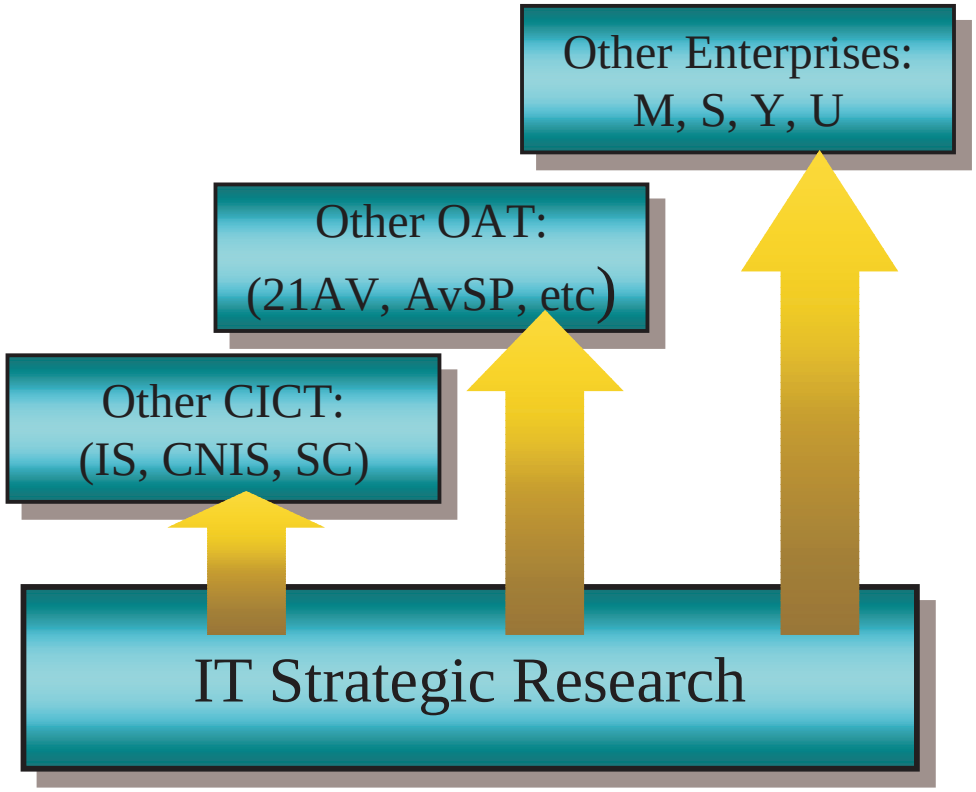


ITSR Project/Program

Reference:	Milestone	Due Date
PCA-8	Bio/nanotechnology device demonstration	September-02
8.1	Design, fabricate and evaluate carbon nanotube electronic devices	September-02
	Fabricate nanoelectronic devise based on CNT nanowire and SAM molecular wire (FAA).	March-02
8.2	Certifiable program synthesis technology	September-02
	Complete initial extended program synthesis engine.	March-02
	Initial prototype for combined certification engine for domain-specific, programming-language specific, and effectiveness properties using annotations generated through program synthesis.	December-02
8.3	Bio-nanotechnology device demonstration	September-02
	Electrochemical detection of DNA hybridization with CNT based sensor device (NCI).	March-02
	Demonstration of nanotube biosensors for detection of cancer molecular signatures (NCI).	December-02
8.4	Nanodevice self-assembly	June-02
	Directed deposition of metals (Zn, Ni, Au) on surfaces using self-assembled protein structures (2D crystals and filaments) to make nano-wires or conduits.	April-02
8.5	Strategic and tactical maneuvering for aerospace vehicles	September-02
	Perform tactical maneuver selection tests in a simulated environment.	
	Integrate capabilities of diagnostics with multimodal interface applied to C-17 engine data.	March-02
8.6	Neuro-electric machine control	September-02
	Analyze signals for EEG-based and demonstrate silent speech	September-02
	Classify at least 8 patterns of sub-vocal speech	June-02

ITSR as Technology Incubator

- IT Strategic Research explores new and revolutionary concepts in information technology, and provides proof-of-concept demonstrations as well as low-TRL technology maturation.
- ITSR technologies are handed off to other CICT Projects, other OAT Programs, and/or other Enterprise Programs and Missions.



ITSR Evolution Plan & Investment Strategy

Selection Criteria:

- Likely to revolutionize some aspect of NASA missions
- Alignment with and impact to Agency Missions and Goals
- Return on Investment assessment
- ITSR Funding Profile
- Critical skills necessary
- Recommendations of external technical advisory committees/Mission Needs Council prioritization
- Current Technology Readiness Level (TRL) (not greater than 6)

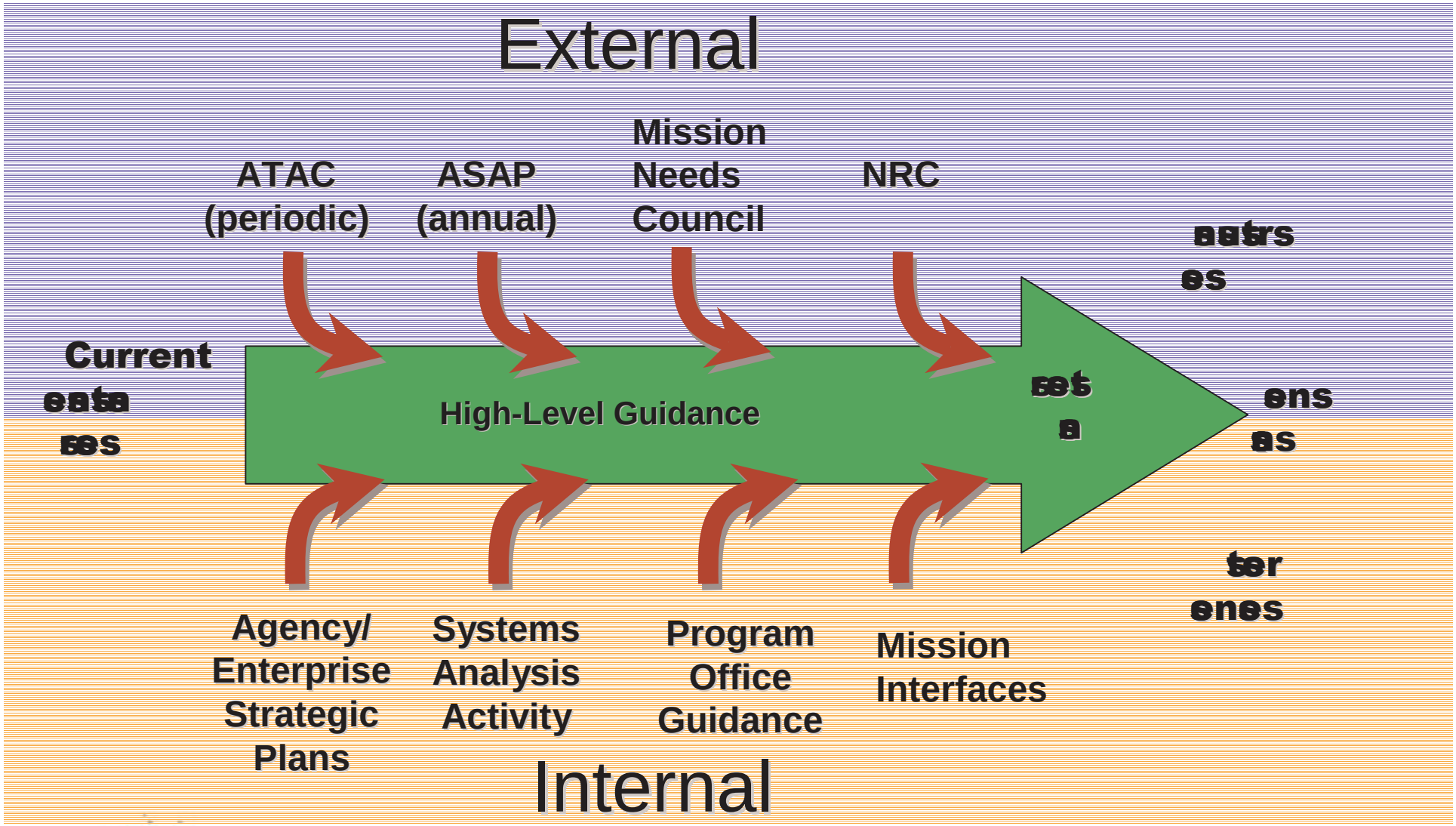
Annual Project Evaluation:

- Agency alignment analysis (qualitative, updated annually)
- ITSR Systems Analysis (quantitative, updated annually)
- Analysis of opportunities
- Project Review

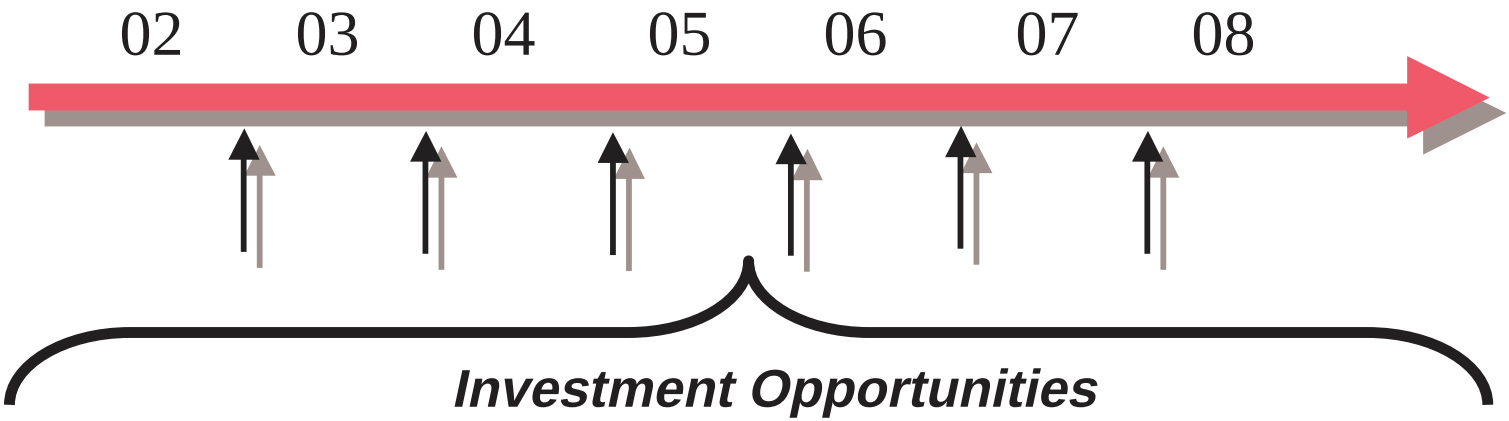
Transfer/Maturation Plan:

- Each investment area has conclusion defined
- Customer(s) Identified and technology transfer plan in place by mid-term of development activities
- No funding beyond TRL 6 - transfer to other project or Program

ITSR Investment Strategy Flow



Sources for ITSR Task/Subtask Genesis



- **Enterprise Programs**
  - **Solicit needs from Enterprises**
  - **Interface with Enterprise advance planning efforts**
- **Proposals on requirements from Mission Needs Council**
- **Code R programs which have CICT requirements which can only be met by developing currently low-TRL technologies**
- **Comments/recommendations from technical advisory committees**
- **Competitive sourcing (NRA, BAA) under general topic areas**
- **Proposals from Enterprise representatives – Code R, Code M, Code U, Code Y, Code S**
- **Proposals from the research staff**

ITSR Agency Alignment

Aerospace Technology

- Increase Safety – Intelligent Controls & Diagnostics
- Increase Mobility – Bio/Nanotechnology – materials
- Mission Safety – Intelligent Controls and Diagnostics, High Confidence Software
- Mission Affordability, Complexity – High Confidence Software
- Mission Reach – Evolvable Systems
- Enable rapid, high confidence, and cost efficient design – ICD, HCS, Evolvable Systems
- Revolutionary Technologies – Revolutionary Computing Algorithms, Intelligent Controls & Diagnostics

Human Exploration and Development of Space

Biological and Physical Research

Space Science

Earth Science

To be fully populated...

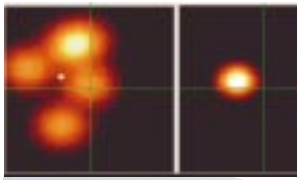
Information Technology Strategic Research

Bio/Nano Technologies

Biomolecular and nanoscale systems and tools for assembly and computing

Evolvable Systems

Autonomous self-improving, self-repairing hardware and software for survivable space systems in extreme environments



IT Strategic Research:

Research, develop and evaluate a broad portfolio of fundamental information and bio/nano technologies for infusion into NASA missions.

Automated Software Engineering Technologies

Formal methods , high-assurance software design, and program synthesis

Revolutionary Computing

New computational models to increase capability and robustness to enable future NASA space missions

Intelligent Controls & Diagnostics

Next-generation machine learning, adaptive control, and health management technologies

Information Technology Strategic Research

(Technology Research Portfolio Overview)

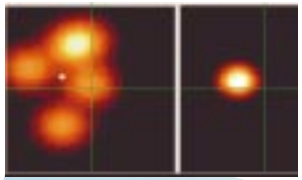
Bio/Nano Technologies

- *Nanoscale Assembly*
- *Nanoscale Electronics & Computing*
- *Biomolecular Systems*

Evolvable Systems

- *Adaptation and Learning*
- *Optimization and Design*
- *Reconfiguration and Reuse*
- *Biologically inspired technologies*

IT Strategic Research:
Research, develop and evaluate a broad portfolio of fundamental information and bio/nano technologies for infusion into NASA missions.



Automated Software Engineering Technologies

- *Formal Methods*
- *High Assurance S/W Design*
- *Program Synthesis*

Revolutionary Computing

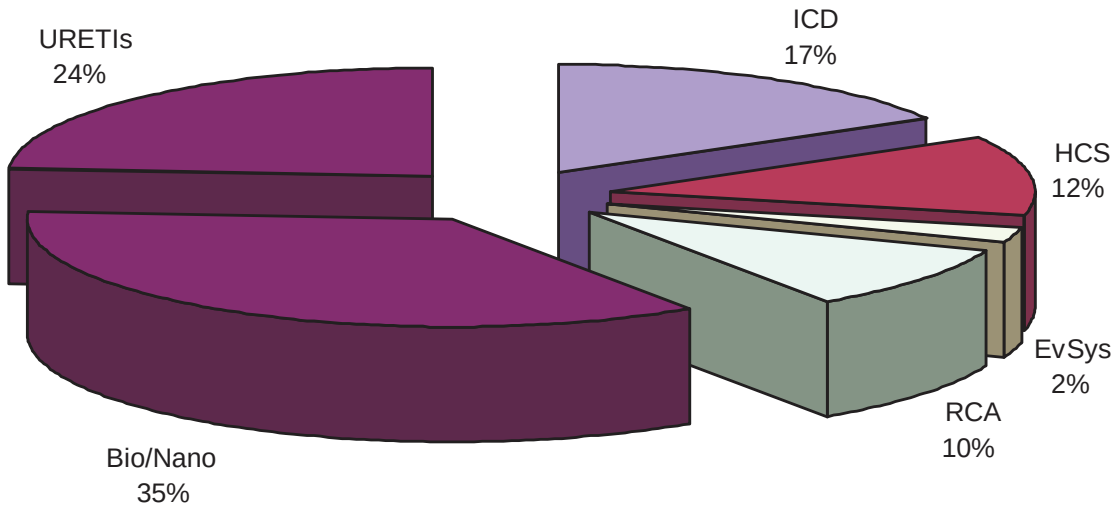
- *Physics-inspired architectures*
- *Biology-inspired architectures*
- *Space computing*

Intelligent Controls & Diagnostics

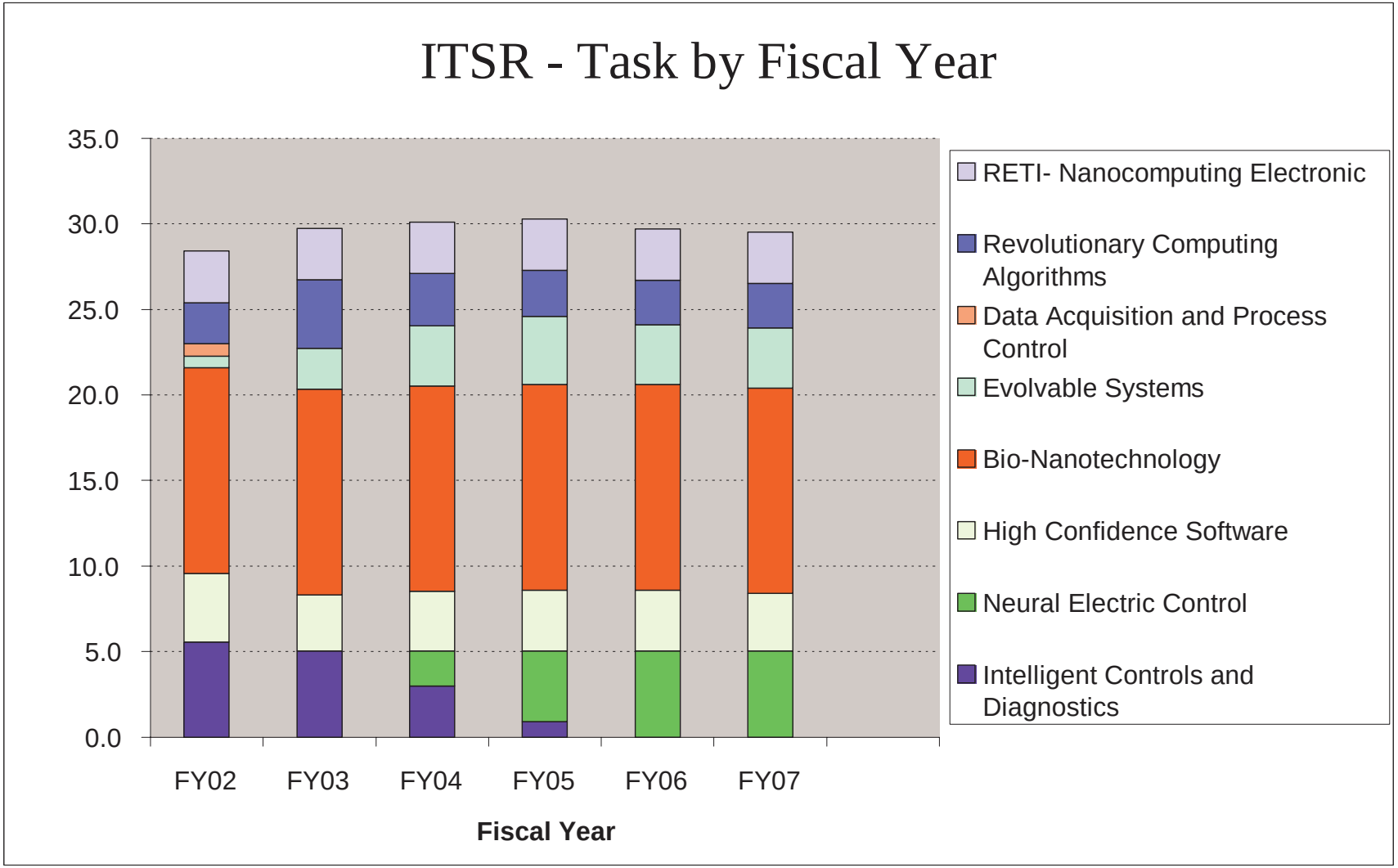
- *Fundamental neural flight control research*
- *Neuroelectric machine control*
- *Intelligent Automation*
- *Smart sensing & diagnostic technologies*

ITSR Resources, FY02

ITSR Funds Distribution, FY02 (Total: $28.4M)



ITSR Funding Profile, Outyears



Automated Software Engineering Technologies

FY02 Distribution ($4.1M)

Goal:

"Develop automated mathematical techniques for the software development process, yielding tools for the cost-effective development of high confidence, highly reliable software systems for aerospace applications."

Technology Development

- Scalable Software model checking
- Automated program abstraction
- State-space search algorithms
- Formal method verification of integrated modular avionics design

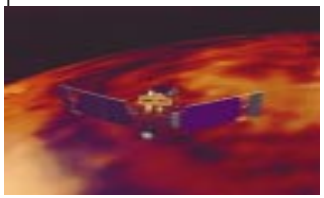
- Program generation through automated reasoning.
- Product-oriented certification methods
- Automated tools that certify automatically synthesized code.

- Generate runtime monitors from requirements specs.
- Automated Behavioral verification
- Machine learning to optimize exploration of potential behaviors.
- Automated generation of software fault recovery.

Capabilities

2002	2003	2006	2007
Analytically verify next-generation Aerospace software.	Certifiable Program Synthesis		Adaptive, Integrated Software Verification and Monitoring Technology

Applications/ Missions



Honeywell, Code S	MDS (Mars'09)	Codes M and S

Target (Impact)

Verification of concurrent, advanced aerospace software architectures and code.	Rapid exploration of design space for navigation software, with new methods for high-confidence and cost-effective certification.	Software that monitors itself, and recovers from faults at runtime with minimal computational overhead.

Intelligent Controls & Diagnostics/Neuro Electric Machine Control

FY02 Distribution ($5.2M)

Goal:

"Improve component/subsystem safety and integrated system performance, as well as reduce development time and operational cost."

Technology Development

- •Hybrid Neural Flight Control System
- •Maneuver Sequence Selection Methods
- •Anomaly Detection Algorithms

- •Trajectory Planning System
- •Integrated H/W & S/W Diagnostics
- •Design Integration Principles for Health Management

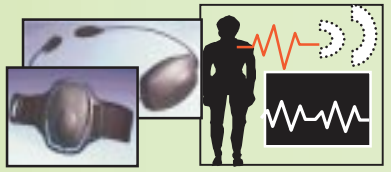
- •Combined EMG/EEG Control
- •Intelligent Automation for Control and Diagnostics

Capabilities

Damage Adaptive Control Engine Health Monitoring	Strategic and Tactical Maneuvering Integrated Controls and Diagnostics	Multi-modal Machine Control Mission-Level Control and Interface

2002 — 2004 — 2006 — 2007

Applications/ Missions



FR and ECS	AvSP and UEET	IS/AR	DARPA and IS/HCC

Target (Impact)

Improved Handling Qualities Following Damage (CH Rating Scale Level Improvement 1-2)	Engine Health/Perf. Monitoring (US Patent for Advanced HUMS New Adaptive Cooling Control For Active Blade Clearance)	Automated Maneuvering System for UAV's (New metrics for Maneuver Selection Effectiveness)	NeuroElectric Interfaces (Improved Human Communication, Monitoring and Control)

Bio/Nanotechnology

FY02 Distribution ($12.4M)

Goal:

Leverage emerging capabilities in the fields of nano-science, information science, and biology into a nanotechnology program focused on unique NASA needs that will revolutionize the way the agency conducts its aerospace missions within a decade.

Nanotechnology **is the science of creating functional materials, devices and systems through control of matter on the nanometer (atomic) scale and the exploitation of novel phenomena and properties at that length scale.**

Technology Development	• Nanoscale, chemical, biological, and physical sensors • Nanopore for gene sequencing • Imaging • Self-assembly	• Nanoelectronics and Computing • Molecular electronics • Quantum and molecular computing • Artificial quantum structures	• Nanomaterials and structures • Multifunctional materials • Lightweight shielding materials • Carbon nanotube composites
Capabilities	Integrated Nanosensor Systems Sensor Arrays	Nanoelectronic brain for space exploration Autonomous spacecraft	Bio-inspired materials and processes Adaptive self-repairing space missions
Target Impact	• Orders of magnitude improvement in sensor sensitivity and coverage • In-situ life detection • Astronaut health monitoring	• Radical new approaches to size reduction and extraordinary speed • Fault tolerant, radiation tolerant electronic devices	• Ultra high strength composites • Smart skin materials • Integral thermal control

Revolutionary Computing Algorithms

FY02 Distribution ($2.6M)

Goal:

- **Develop new *models of computation* that increase capability and robustness to enable future NASA space missions**

Technology Development Highlights

- Information representation schemes based on examples in biology and quantum physics
- Co evolutionary search
- Cerebellum models for robot control
- Data search and computation using molecular self-assembly
- Time synchronization using quantum entanglement
- Quantum computation algorithms for hard problems

Impact

Design
Optimization
Distributed control
(2004-2006)

Robot control
Exquisite detection
(2005-2008)

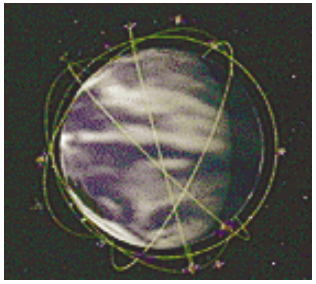
Interferometry
Planning & Scheduling
Data search
(2006-2010)

Applications/ Missions

Exploration

Titan Explorer

Europa Hydrobot



Sensor Web

Evolvable Systems

FY02 Distribution ($600k)

Goal:

"To dramatically increase mission survivability and science return through development and application of evolutionary and adaptive algorithms."

Technology Development

- Advanced Evolutionary Algorithms
- Automated Design and Optimization
- Evolvable Scheduling Algorithms
- Adaptive Sensor Suite
- In-situ Adaptive Hardware

Future

- Defect Tolerant Systems
- Distributed Control
- Self-Reconfiguration for Survivability
- Evolved Control Algorithms

Capabilities

Adaptive, In-Situ Reconfiguration	Evolved Hardware for Extreme Environments	Evolvable Robotic Control

Target (Impact)

Automatic Fault Recovery

Electronics Automatically Rewire Following Damage

Extreme Environments

Electronics Survives Extreme Radiation, Temperature

Planetary Exploration

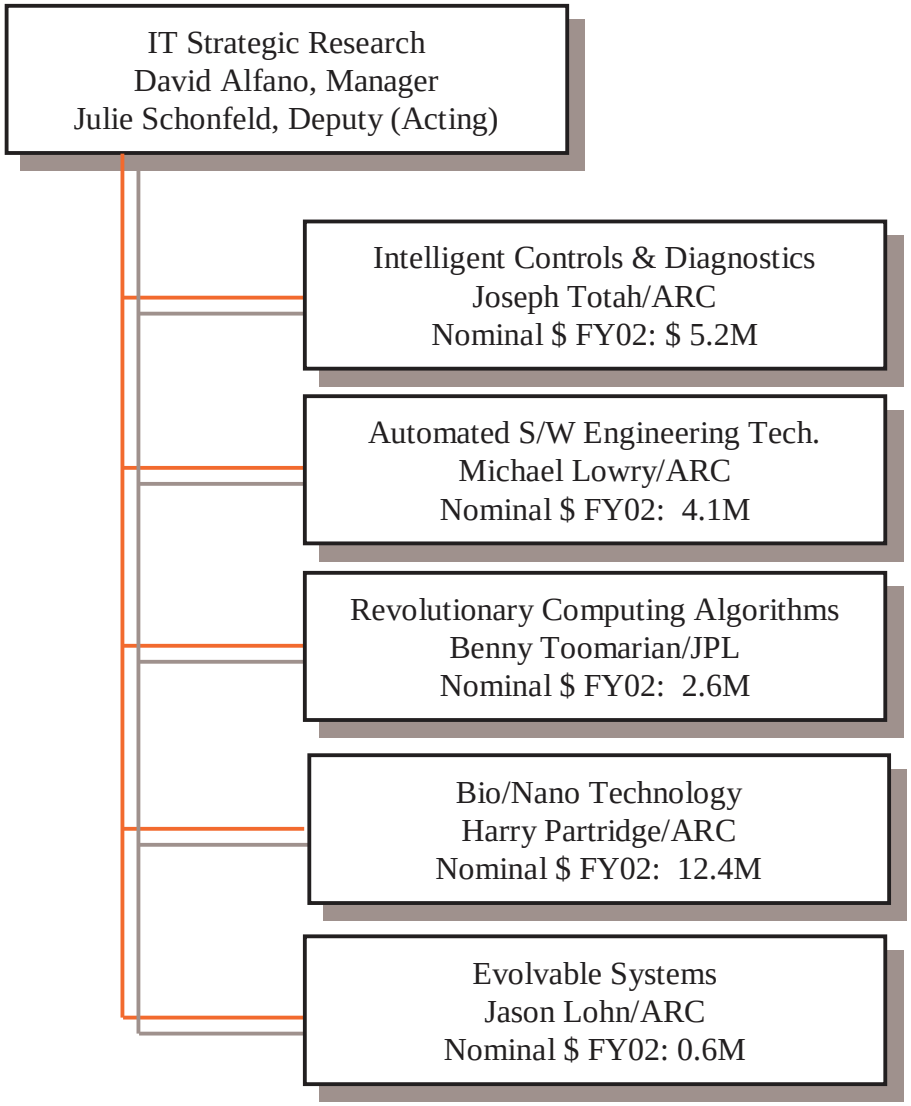
Evolved Controller Circuits for Mobile Drilling

Distributed Robotic Control

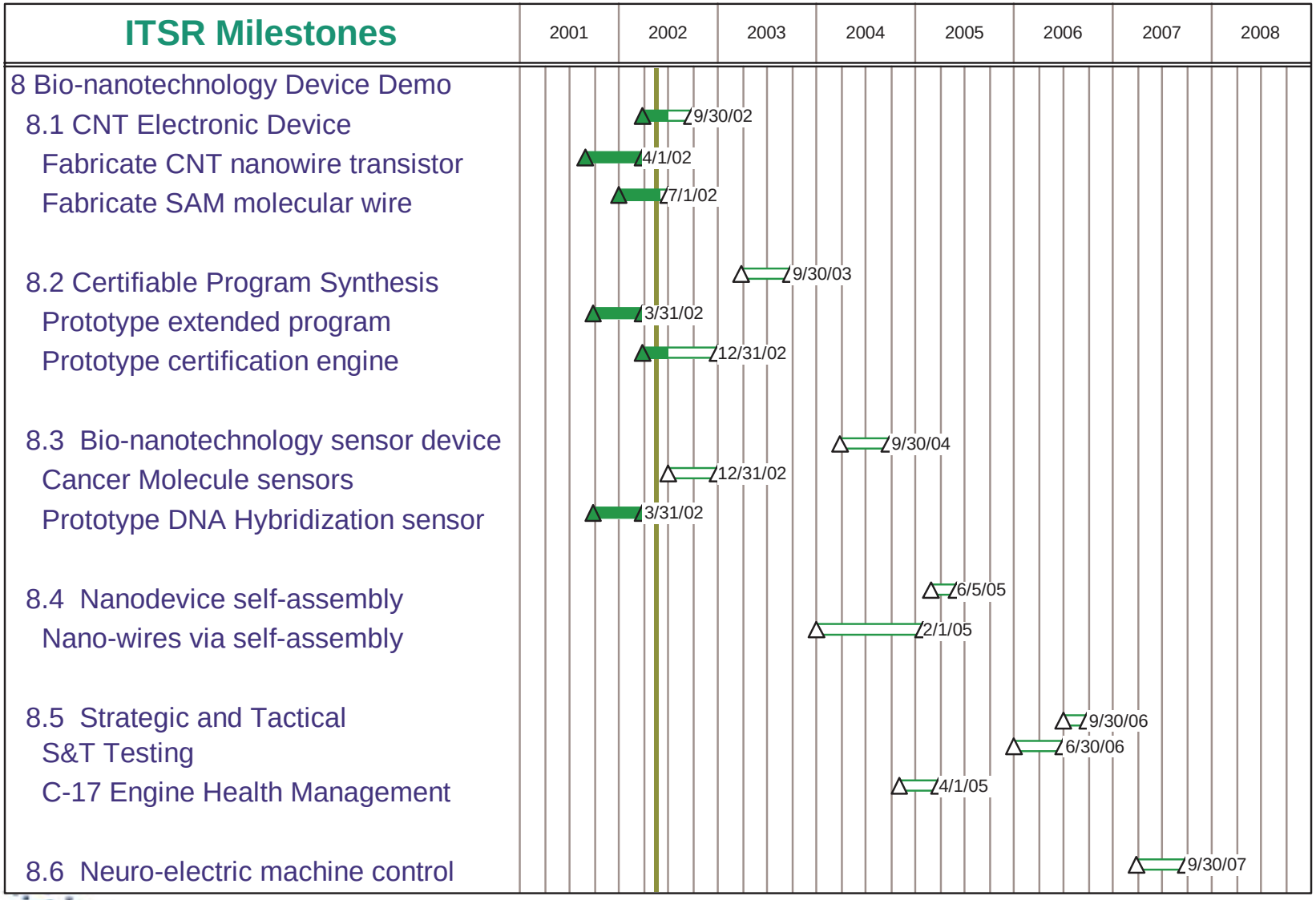
Coordination Among Robotic Structures

Backup Slides

ITSR Organization



ITSR Level 1 Milestones

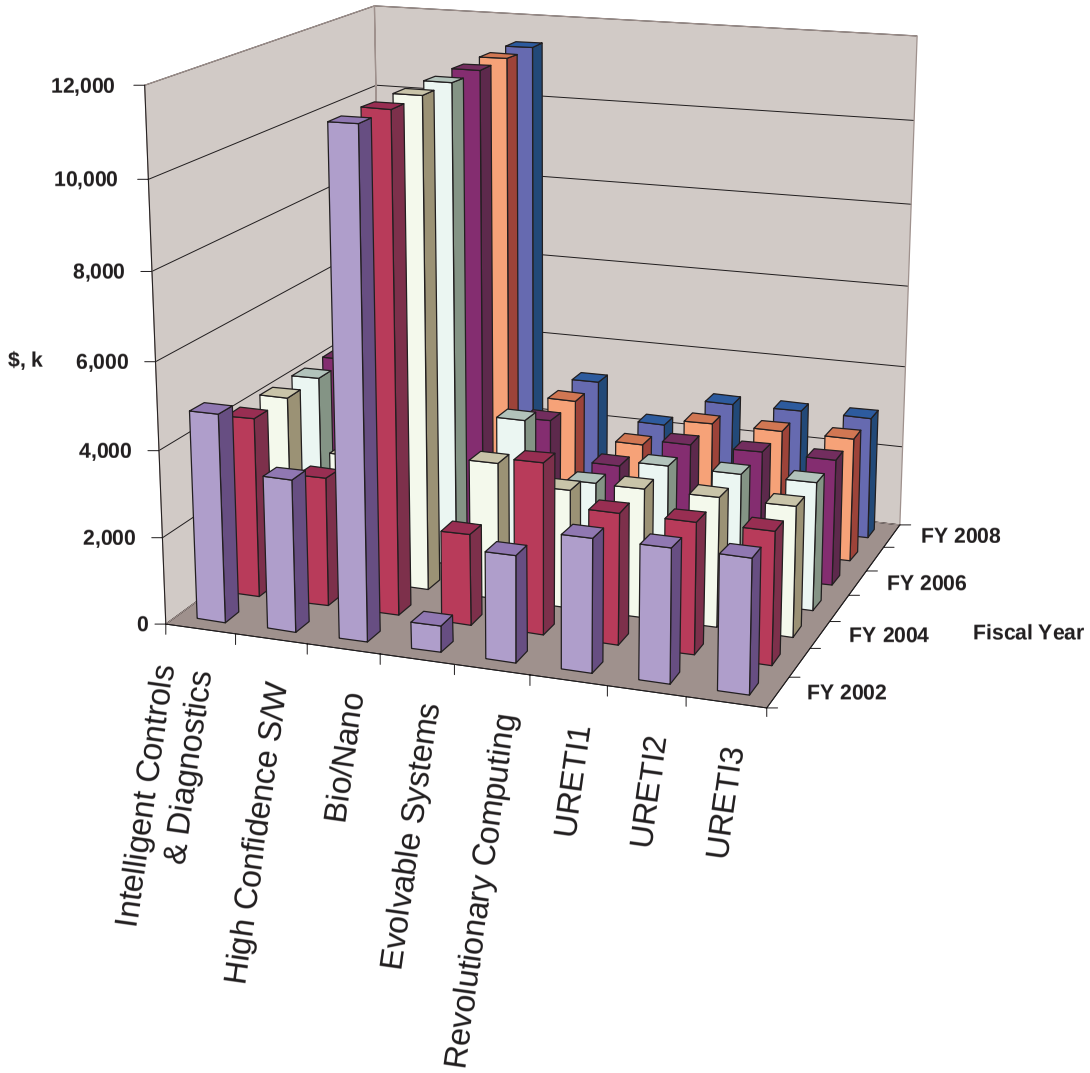


ITSR Funding Profile - detail

3/22/02	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
Information Technology Strategic Research	29,464	27,635	27,582	27,712	27,112	27,112	27,112
Intelligent Controls and Diagnostics	4,800	4,200	4,200	4,200	4,200	4,200	4,200
High Confidence Software	3,500	3,000	3,000	3,000	3,000	3,000	3,000
Bio/Nano	11,400	11,400	11,400	11,400	11,400	11,400	11,400
Evolvable Systems	600	2,100	3,212	3,712	3,212	3,212	3,212
Revolutionary Computing Algorithms	2,414	2,435	2,771	2,400	2,300	2,300	2,300
URETI- Nanocomputing Electronics	3,000	3,000	3,000	3,000	3,000	3,000	3,000
URETI- Bio/Nano/IT Fusion	3,000	3,000	3,000	3,000	3,000	3,000	3,000
URETI-Nanostructures & Materials	3,000	3,000	3,000	3,000	3,000	3,000	3,000

update per PFP

ITSR Funding Profile - Outyears



Information Technology Strategic Research

Contact Information

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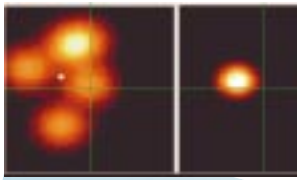

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